Investigating the relationship between ozone and water-ice clouds using retrieved data from the ExoMars Trace Gas Orbiter

Investigating the Relationship Between Ozone and Water-Ice Clouds Using Data From the ExoMars Trace Gas Orbiter

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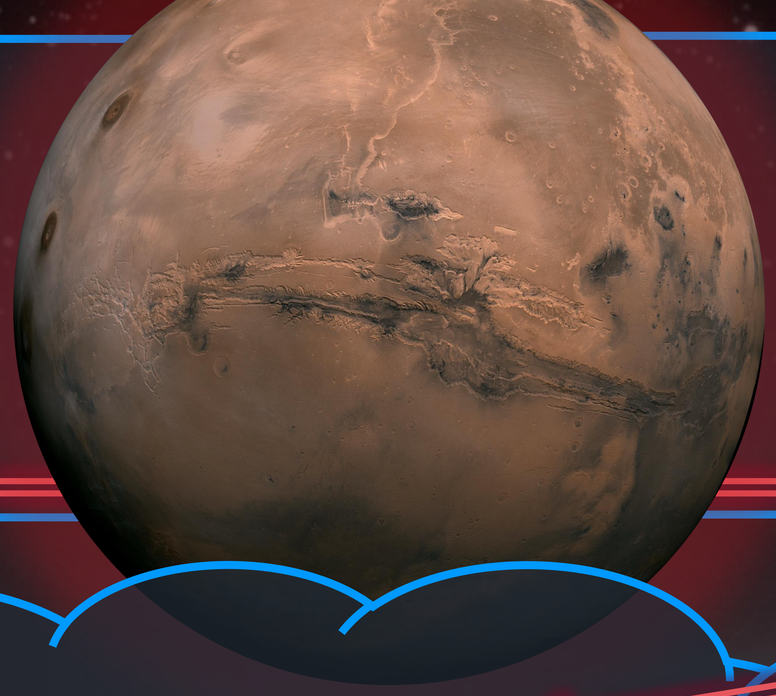


Background: Ozone on Mars

Ozone is a trace gas in the martian atmosphere (<0.01%)[1] and is:

- Formed by photodissociation of CO_2[1,2]
- Absorbent, breaking down in the ultra violet (UV) region (220–280 nm)[1,2]
- Photosensitive[2,4,12]
- Anti-correlated with water vapour[4,10,12]
- Seasonal with diurnal variation[2]

Importance: why we care

Ozone is dependant on other atmospheric species and has a short lifetime:

- **Tracking global wind patterns**[8]

with little photochemical destruction which extends its average lifetime

- **Proxy for water vapour and trace gases**[11,12]

such as hydroxyl radicals which are necessary to keeping the CO_2 in the atmosphere stable.

- **Understanding photochemical processes**[9,10]

Ozone–water anticorrelation

- Photolysis of water vapour produces hydroxyl radicals (HO_x)[2,12]
- HO_x are highly reactive and destroy ozone:

$$H_2O + h\nu \rightarrow HO + H_2$$
$$HO + O \rightarrow HO_2$$
$$O_3 + HO_2 \rightarrow HO + 2O_2$$

where $h\nu$ is sunlight.

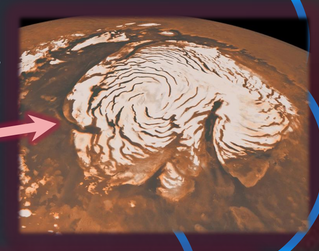
- Water vapour abundance reduces in colder seasons and ozone can form in its absence[4]
- Ozone detected at similar altitudes to water-ice clouds[7,11]

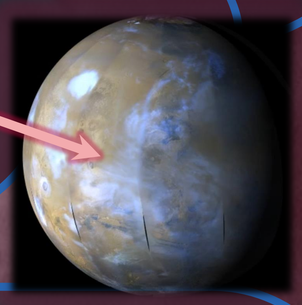
→ ozone–water relationship is not universal to all states of water

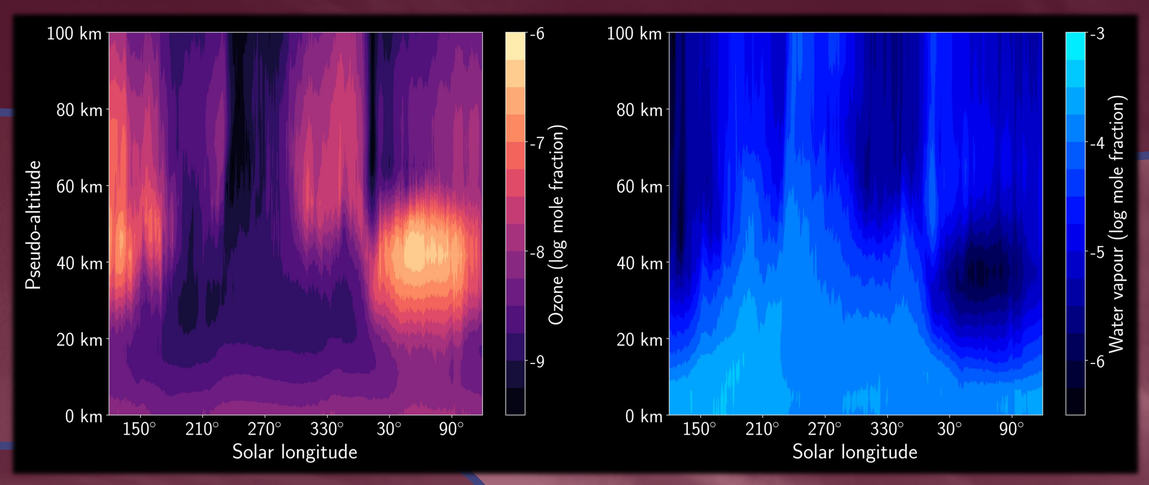
Clouds on Mars

Most water-ice clouds form at the water vapour saturation level. Three main types of clouds[5,6,11]:

- Orographic
- **Polar hoods**
  - → Higher Opacity
  - → Larger particle size
- **Aphelion Cloud Belt**







Observations: Trace Gas Orbiter

▲ One of the Trace Gas Orbiter's (TGO's) main missions includes mapping trace gases in the martian atmosphere[14]

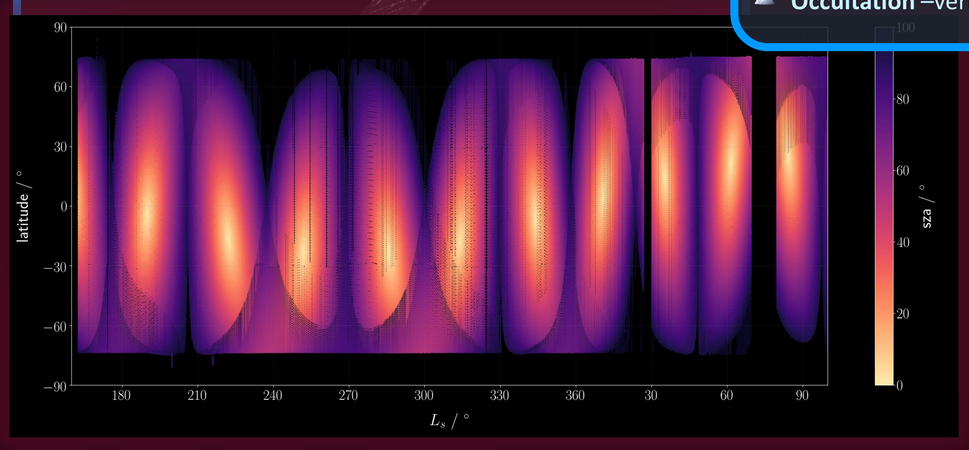
▲ NOMAD (Nadir and Occultation for Mars Discovery) is an instrument aboard TGO which contains a UV and visible spectrometer, UVIS[13]

▲ Both ozone and water-ice are detected in the UV region and so retrieved data from UVIS will be used to investigate the ozone and water-ice

▲ Data will be temporally and spatially binned to visualise patterns

▲ Correlation tests to compare ozone and water-ice in different cloud regions

Below shows the nadir latitudinal coverage of UVIS since it began scientific mapping back in April 2018



UVIS has two observational modes:

- **Nadir** –spatial coverage and total column abundance
- **Occultation** –vertical profiles

Hypothesis: Water-ice chemistry

<u>Known:</u>

▲ Water-ice and ozone relationship are used as a proxy for HO_x[4,9]

▲ Global climate models (GCMs) are in disagreement of HO_x and water-ice chemistry[4,9]

▲ Two types of chemistry GCMs were tried (figure below)[4]:

- Heterogeneous – **positive** correlation between ozone and water-ice → destruction of HO_x via water-ice clouds allows ozone to form
- Homogeneous – **negative** correlation between ozone and water-ice → HO_x is unaffected by water-ice clouds and can destroy ozone

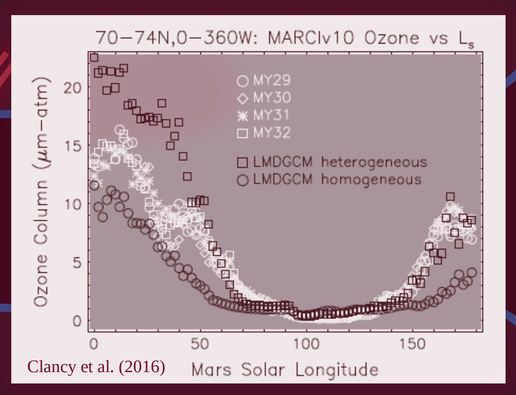
<u>Unknown:</u>

▲ Ozone near water-ice cloud regions

→ Chemical processes preventing the destruction of ozone from HO_x.

▲ Positive correlation

→ water-ice clouds act as a sink for hydroxyl radicals



Clancy et al. (2016)

Next steps

- Examine the relationship between water-ice and ozone at different latitudes
- Use UVIS vertical profiles to compare altitudes of ozone and water-ice layers
- Heterogeneous chemistry is dependent on particle size: compare different cloud regions with ozone
- Investigate heterogeneous and homogeneous chemistry throughout the martian year

References: [1]Barth et al (1973); [2]Clancy and Nair (1996); [3]Clancy et al (2003); [4]Clancy et al. (2016); [5]Benson et al. (2010); [6]Benson et al. (2011); [7]Bertaux et al. (2006); [8]Holmes et al. (2017); [9]Lefèvre et al. (2004); [10]Lefèvre et al. (2008); [11]Lefèvre and Montmessin (2013); [12]Montmessin et al. (2004); [13]Patel et al. (2017); [14]Vandaele et al. (2018); [15]Willame et al (2017)

Credit (figures/images): NASA, ESA, UVIS Working Team (Open University), Clancy et al. (2016), planetary.s3.amazonaws.com, thusspokejon.files.wordpress.com